SGM6016
1.2A, 1.6MHz, High Efficiency Synchronous Step-Down Converter

GENERAL DESCRIPTION

SGM6016 is a 1.2A, 1.6MHz step-down regulator, which is ideal for powering low-voltage microprocessors in compact devices such as GPS and cellular phones. It is optimized for generating low output voltages down to 0.8V. The supply voltage range is from 2.7V to 5.5V allowing the use of a single Li+ cell, three NiMH cells or a regulated 5V input. 1.6MHz pulse-width modulation (PWM) switching frequency allows using small external components. It has flexible operation mode selection of forced PWM mode and skip (low I_Q) mode with typical 30μA quiescent current for highest light load efficiency to maximize battery life.

The SGM6016 integrates a pair of low on-resistance P-Channel and N-Channel MOSFETs to maximize efficiency and minimize external component count.

The SGM6016 offers a typical 215ms power-good (PG) timer when powered up. The timer output can be reset by RSI. When shut down, SGM6016 discharges the output capacitor. Other features include internal digital soft-start, enable for power sequence, over-current protection and thermal shutdown.

SGM6016 is available in the Green TDFN-3×3-10L package. It is rated over the -40℃ to +85℃ temperature range.

FEATURES

- **High Efficiency Up to 95%**
- **2.7V to 5.5V Supply Voltage**
- **Very Low Quiescent Current: 30μA in Skip Mode**
- **1.2A Guaranteed Output Current**
- **3.7% Output Accuracy Over Temperature**
- **Selectable Forced PWM Mode and Skip Mode**
- **Less than 1μA Shutdown Current**
- **100% Maximum Duty Cycle for Lowest Dropout**
- **Discharge Output Capacitor when Shut Down**
- **Internal Digital Soft-Start**
- **Peak Current Limiting, Short Circuit Protection**
- **Over-Temperature Protection**
- **Enable and Power-Good Functions**
- **Available in Green TDFN-3×3-10L Package**

APPLICATIONS

Single Li-ion Battery-Powered Equipment
DSP Core Power
GPS and Palmtops

PACKAGE/ORDERING INFORMATION

MODEL	PIN-PACKAGE	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKAGE OPTION
SGM6016	TDFN-3×3-10L	-40℃ to +85℃	SGM6016YTD10G/TR	SGM 6016D XXXXX	Tape and Reel, 3000

NOTE: **XXXXX** = Date Code and Vendor Code.

ABSOLUTE MAXIMUM RATINGS

VIN...-0.3V to 6V
FB, SW, EN, RSI, MODE, PG ....-0.3V to V_{IN} + 0.3V
Operating Temperature Range............................-40℃ to +85℃
Junction Temperature...150℃
Storage Temperature Range.............................-65℃ to +150℃
Package Thermal Resistance
TDFN-3×3-10L, θ_{JA}…………………………………….....50℃/W
Lead Temperature (Soldering, 10s) ....260℃
ESD Susceptibility
HBM... 4000V
MM... 200V

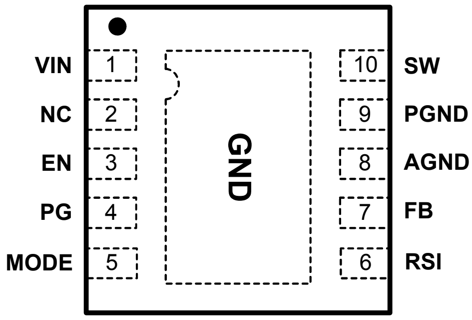
NOTE:
Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

CAUTION

This integrated circuit can be damaged by ESD if you don’t pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

SGMICRO reserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time. Please contact SGMICRO sales office to get the latest datasheet.

PIN CONFIGURATION (TOP VIEW)



TDFN-3×3-10L

PIN DESCRIPTION

PIN	NAME	FUNCTION
1	VIN	Input Supply Voltage. Connect a 10μF ceramic capacitor to power ground.
2	NC	No Internal Connection.
3	EN	Enable Pin. Enable the device when driven to high. Shut down the chip and discharge output capacitor when driven to low. Do not leave this pin floating.
4	PG	Power-Good Signal. 215ms timer output. This output is a 215ms delayed power-good signal (PG) for the output voltage when output voltage is within the power-good window. It can be reset by a high RSI signal, then the 215ms timer starts when RSI goes from high to low.
5	MODE	Mode Selection Pin. Connect it to logic high or input voltage VIN for low I_Q skip mode, and connect it to logic low or ground for forced PWM mode. Do not leave this pin floating.
6	RSI	RSI Signal. This input resets the 215ms timer. When the output voltage is within the power-good window, an internal timer is started and generates a PG signal 215ms later when RSI is low. A high RSI resets PG and RSI high to low transition restarts the internal counter if the output voltage is within the window, otherwise the counter is reset by the output voltage condition. Do not leave this pin floating.
7	FB	Buck Regulator Output Feedback Pin. Connect it to the output through voltage divider resistor for adjustable output voltage.
8	AGND	Analog Ground. AGND and PGND should only have connection at one point.
9	PGND	Power Ground. Connect all power grounds to this pin.
10	SW	Switching Node Connection. Connected to one terminal of inductor.
Exposed Pad	GND	The exposed pad must be connected to the PGND pin for proper electrical performance. The exposed pad must also be connected to the PGND as much as possible for optimal thermal performance.

ELECTRICAL CHARACTERISTICS

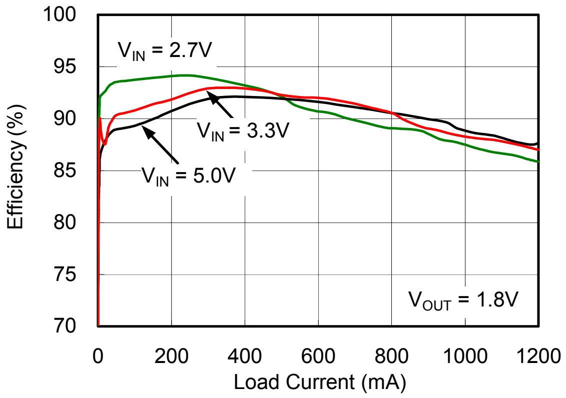
(V_{IN} = V_{EN} = V_{MODE} = 3.6V, V_{RSI} = 0V, L1 = 2.2μH, C_{IN} = C_{OUT} = 10μF, I_{OUT} = 0A, Full = -40℃ to +85℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}		Full	2.7		5.5	V
Feedback Input Bias Current	I_{FB}	V_{FB} = 0.75V	+25℃		0.1		μA
Regulated Feedback Voltage	V_{FB}	T_A = 0℃ to +85℃		0.777	0.800	0.823	V
			Full	0.774	0.800	0.826	
Quiescent Current	I_Q	MODE = V_{IN}, no load at the output	+25℃		30	60	μA
		MODE = AGND, no load at the output			3.5	4.5	mA
Shutdown Current	I_{SD}	V_{IN} = 5.5V, EN = LOW	+25℃		0.05	1	μA
Under-Voltage Lockout Threshold	V_{UVLO}	Rising	+25℃		2.35	2.68	V
		Falling		2.1	2.25		
Output Voltage Accuracy		V_{IN} = 3.6V, I_{OUT} = 200mA, V_{OUT} = 1.6V	Full	-3.7		3.7	%
Output Voltage Line Regulation	ΔV_{OUT}	V_{IN} = 2.7V to 5.5V, V_{OUT} = 1.6V	Full		0.2		%/V
Maximum Output Current			+25℃	1.2			A
Error Amplifier Transconductance	gm	Design info only	+25℃		13		μA/V
P-Channel MOSFET On-Resistance		V_{IN} = 3.6V, I_{OUT} = 200mA	+25℃		0.15	0.30	Ω
		V_{IN} = 2.7V, I_{OUT} = 200mA			0.18	0.32	
N-Channel MOSFET On-Resistance		V_{IN} = 3.6V, I_{OUT} = 200mA	+25℃		0.12	0.30	Ω
		V_{IN} = 2.7V, I_{OUT} = 200mA			0.13	0.32	
N-Channel Bleeding MOSFET On-Resistance			+25℃		90		Ω
P-Channel MOSFET Peak Current Limit	I_{PK}	V_{IN} = 5.5V	+25℃	1.40	1.75	2.10	A
Maximum Duty Cycle			+25℃		100		%
PWM Switching Frequency	f_S		Full	1.3	1.6	1.8	MHz
SW Minimum On Time		MODE = LOW (forced PWM mode)	+25℃		160		ns
Soft Start-Up Time			+25℃		1.1		ms
PG Pin Output Low Voltage		Sinking 1mA, V_{FB} = 0.7V	+25℃			0.3	V
PG Pin Delay Time			+25℃	170	215	260	ms
PG Pin Leakage Current		PG = V_{IN} = 3.6V	+25℃		0.01	1	μA
Minimum Supply Voltage for Valid PG Signal			+25℃	1.2			V
Internal PGOOD Low Rising Threshold		Percentage of nominal regulation voltage	+25℃	89	92	95	%
Internal PGOOD Low Falling Threshold		Percentage of nominal regulation voltage	+25℃	85	88	91	%
Internal PGOOD High Rising Threshold		Percentage of nominal regulation voltage	+25℃	109	112	115	%
Internal PGOOD High Falling Threshold		Percentage of nominal regulation voltage	+25℃	105.5	108.5	111.5	%
Internal PGOOD Delay Time			+25℃		50		μs
Logic Input Low Voltage	V_{IL}		+25℃			0.4	V
Logic Input High Voltage	V_{IH}		+25℃	1.5			V
Logic Input Leakage Current		Pulled up to 5.5V	+25℃		0.1	1	μA
Thermal Shutdown			+25℃		150		℃
Thermal Shutdown Hysteresis			+25℃		15		℃

TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = V_{EN} = V_{MODE} = 3.6V$, $V_{RSI} = 0V$, L1 = 2.2μH, $C_{IN} = C_{OUT} = 10μF$, $I_{OUT} = 0A$, $T_A = +25℃$, unless otherwise noted.

Efficiency vs. Load Current



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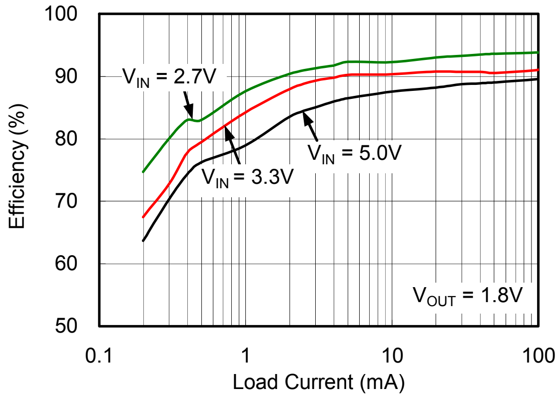

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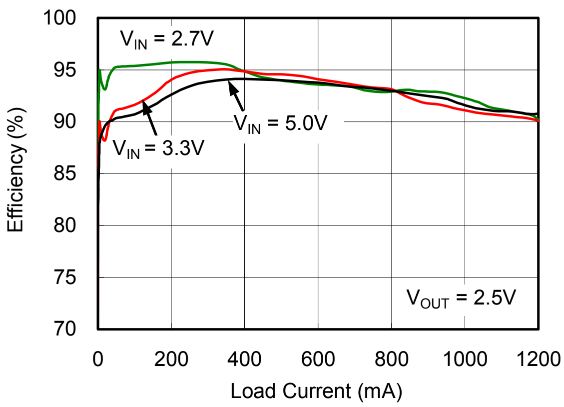

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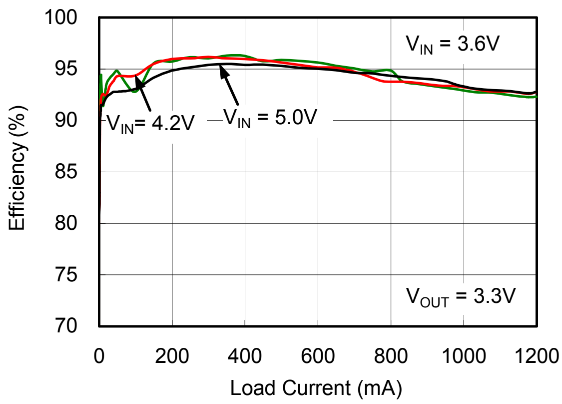
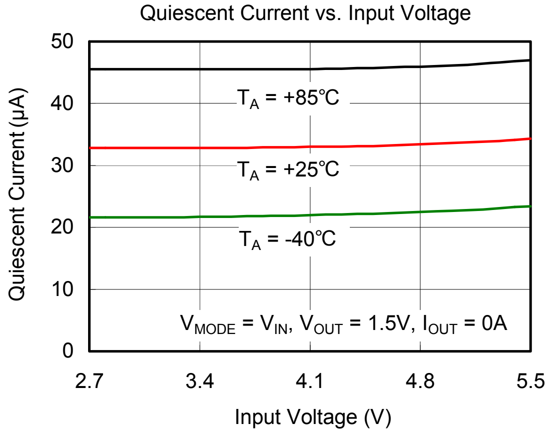
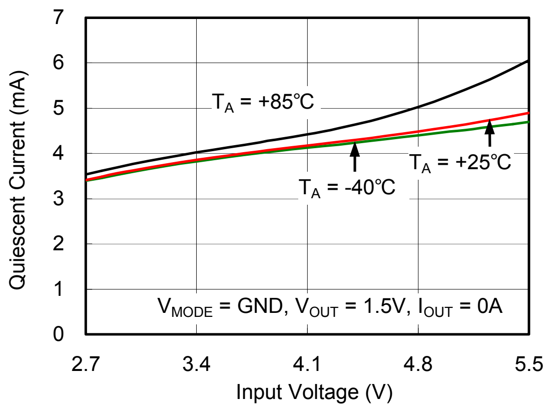


Quiescent Current vs. Input Voltage



Quiescent Current vs. Input Voltage



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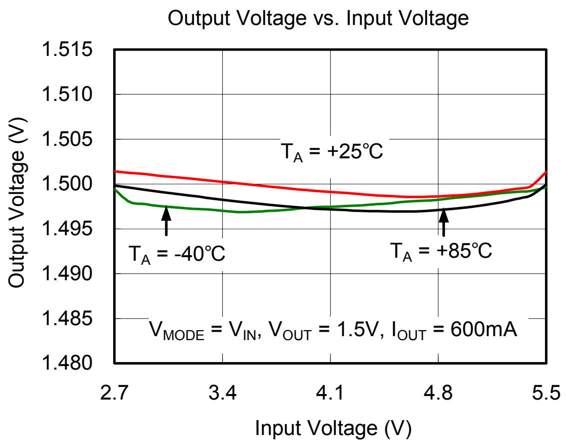

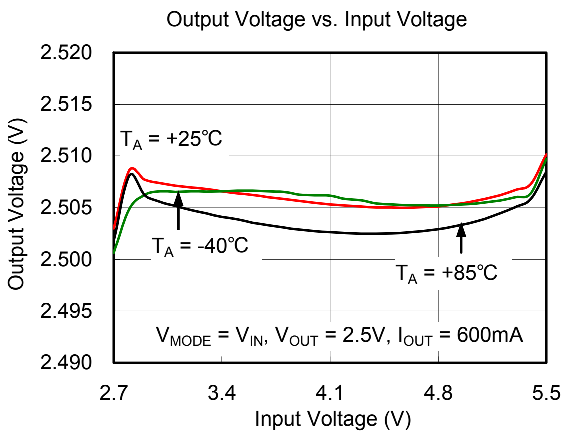

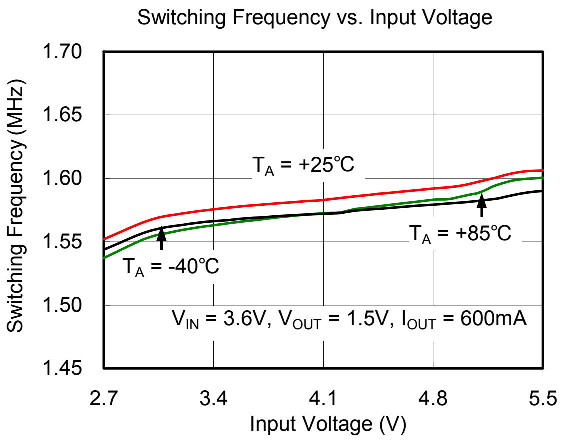

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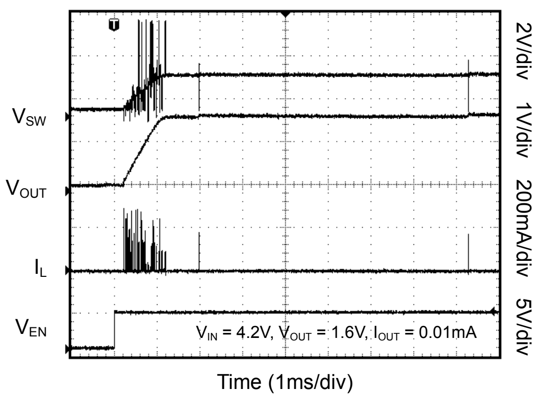
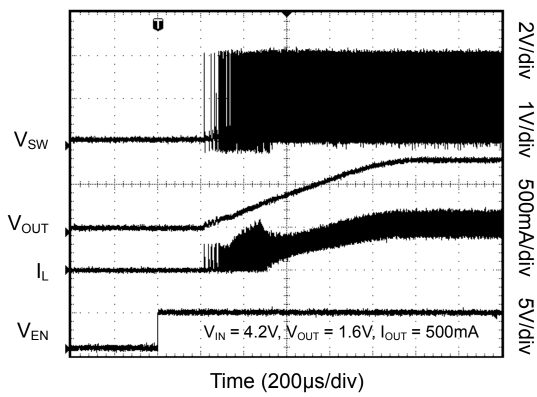
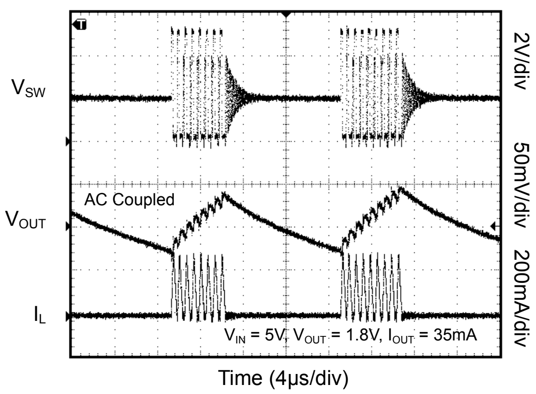
Soft-Start to Skip Mode



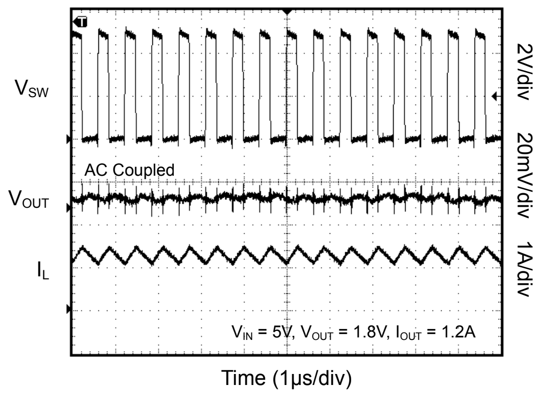
Soft-Start to PWM Mode



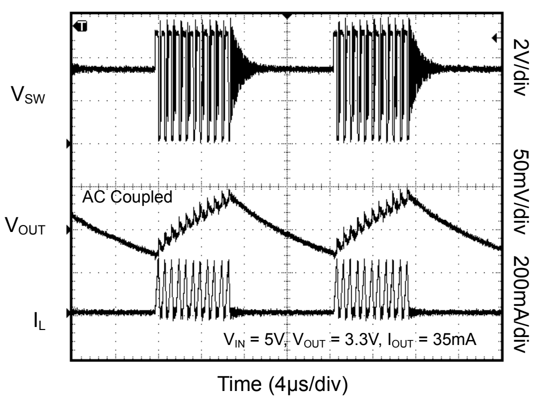
Steady-State in Skip Mode



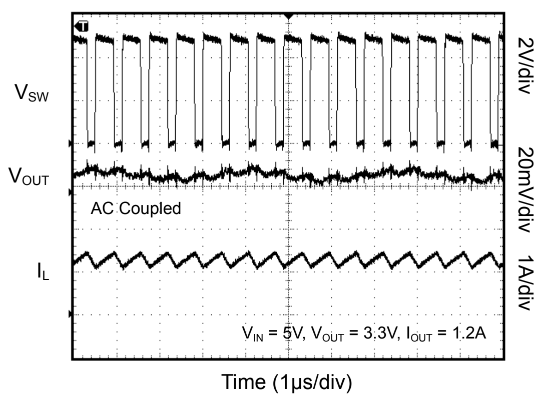
Steady-State in PWM Mode



Steady-State in Skip Mode



Steady-State in PWM Mode



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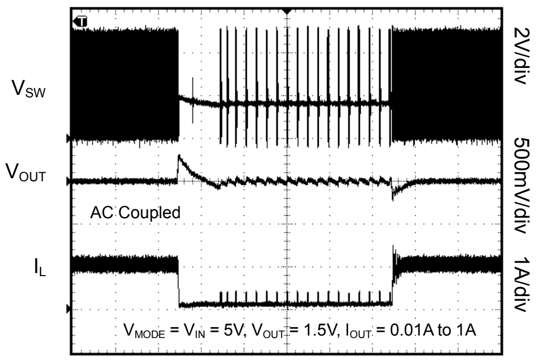
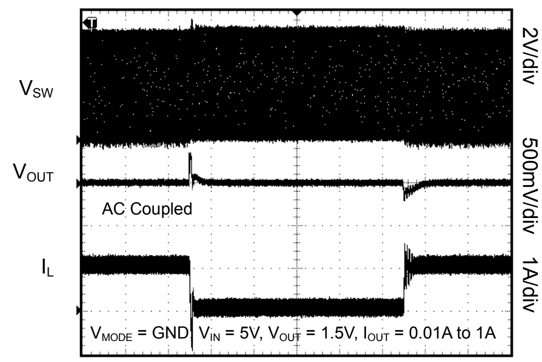
Load Transient Test



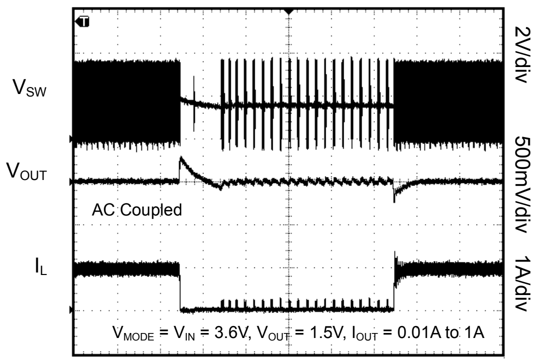
Time (100μs/div)

Load Transient Test



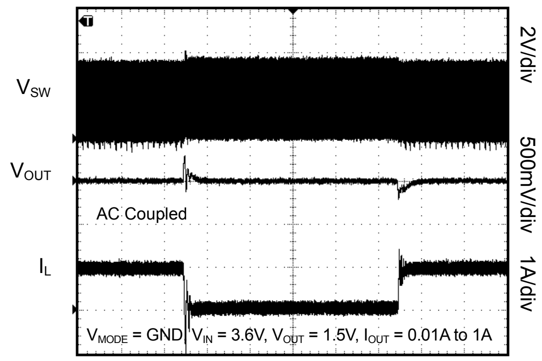
Time (100μs/div)

Load Transient Test



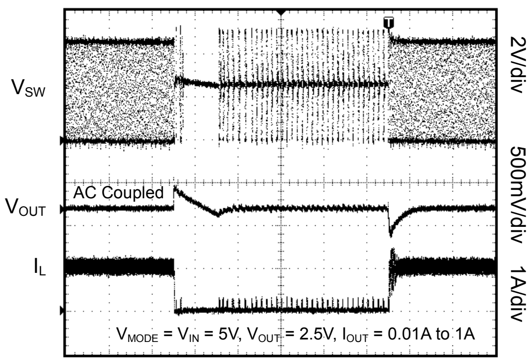
Time (100μs/div)

Load Transient Test



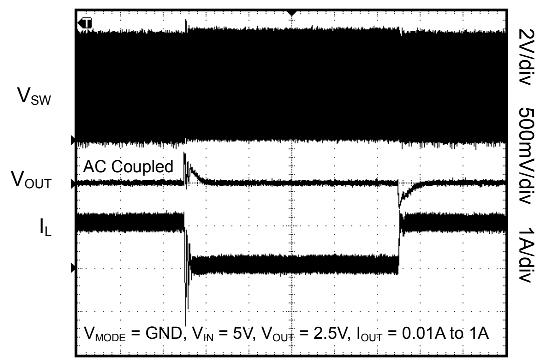
Time (100μs/div)

Load Transient Test



Time (100μs/div)

Load Transient Test



Time (100μs/div)

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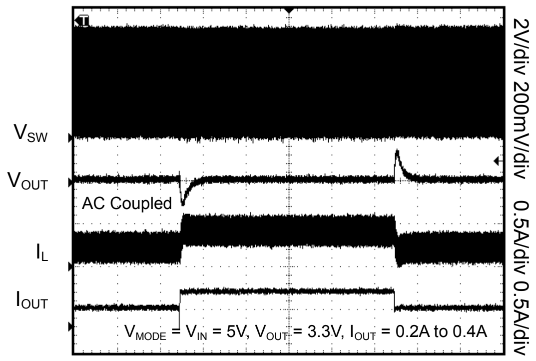
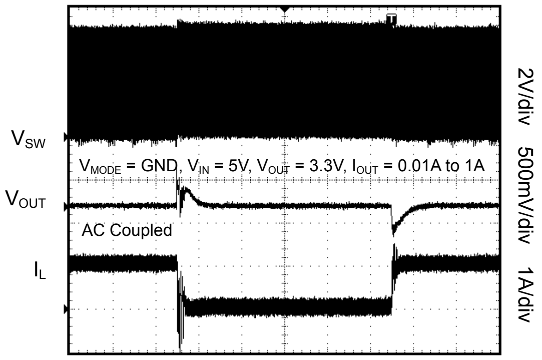


Time (100μs/div)

Load Transient Test



Time (100μs/div)

TYPICAL APPLICATION

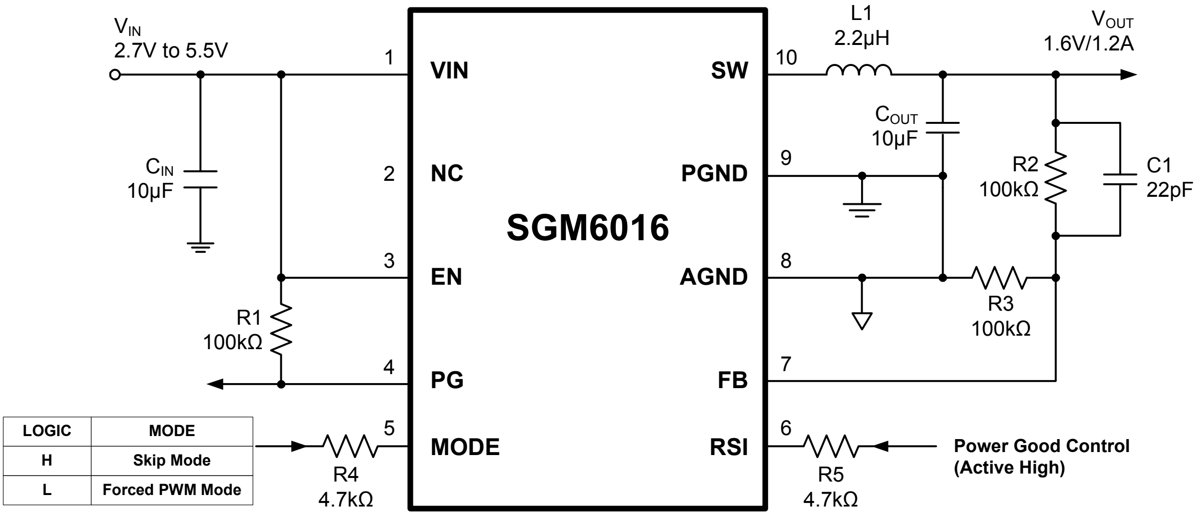


Table 1. Standard 1% Resistor Values for Output Voltages

V_{OUT} (V)	L1 (μH)	C_{OUT} (μF)	C1 (pF)	R2 (kΩ)	R3 (kΩ)
0.8	2.2	22	22	0	100
1.0	2.2	22	22	44.2	178
1.2	2.2	22	22	80.6	162
1.5	2.2	22	22	84.5	97.6
1.8	2.2	10	22	100	80.6
2.5	2.2	10	22	100	47.5
2.8	2.2	10	22	100	40.2
3.3	2.2	10	22	102	32.4

APPLICATION INFORMATION

Inductor and Output Capacitor Selection

To achieve better steady state and transient response, the SGM6016 typically uses a 2.2μH inductor. The peak-to-peak inductor current ripple can be expressed as follows:

$$\Delta I = \frac{V_{OUT} \times (1 - \frac{V_{OUT}}{V_{IN}})}{L1 \times f_S} \quad (1)$$

In Equation 1, usually the typical values can be used but to have a more conservative estimation, the inductance should consider the value with worst case tolerance; and for switching frequency f_S, the minimum f_S from the "Electrical Characteristics" table can be used.

To select the inductor, its saturation current rating should be at least higher than the sum of the maximum output current and half of the delta calculated from Equation 1. Another more conservative approach is to select the inductor with the current rating higher than the P-Channel MOSFET peak current limit.

Another consideration is the inductor DC resistance since it directly affects the efficiency of the converter. Ideally, the inductor with the lower DC resistance should be considered to achieve higher efficiency.

Inductor specifications could be different from different manufacturers, so please check with each manufacturer if additional information is needed.

For the output capacitor, a ceramic capacitor can be used because of the low ESR value which helps to minimize the output voltage ripple. A typical value of 10μF/6.3V ceramic capacitor should be enough for most of the applications and the capacitor should be X5R or X7R.

Input Capacitor Selection

The main function for the input capacitor is to provide decoupling of the parasitic inductance and to provide filtering function to prevent the switching current from flowing back to the battery rail. A 10μF/6.3V ceramic capacitor (X5R or X7R) is a good starting point for the input capacitor selection.

Output Voltage Setting Resistor Selection

The voltage divider resistors, R2 and R3, as shown in Typical Application, set the desired output voltage value. The output voltage can be calculated using Equation 2:

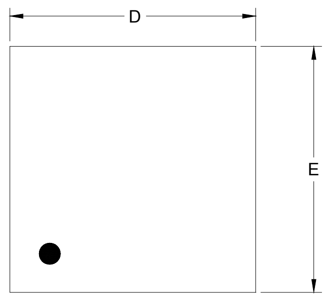
$$V_{OUT} = V_{FB} \times (1 + \frac{R2}{R3}) \quad (2)$$

where V_{FB} is the feedback voltage (typically it is 0.8V). The current flowing through the voltage divider resistors can be calculated as V_{OUT}/(R2 + R3), so larger resistance is desirable to minimize this current. On the other hand, the FB pin has leakage current that will cause error in the output voltage setting. The leakage current has a typical value of 0.1μA. To minimize the accuracy impact on the output voltage, select the R3 no larger than 200kΩ.

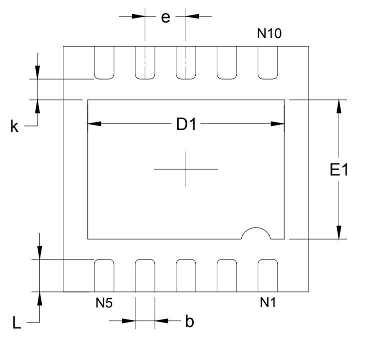
C1 is highly recommended to be added for improving stability and achieving better transient response.

PACKAGE OUTLINE DIMENSIONS

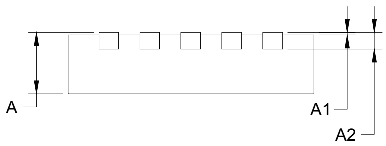
TDFN-3×3-10L



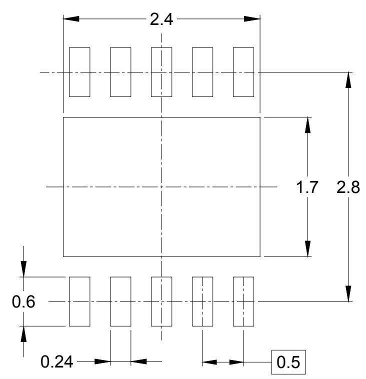
TOP VIEW



BOTTOM VIEW



SIDE VIEW

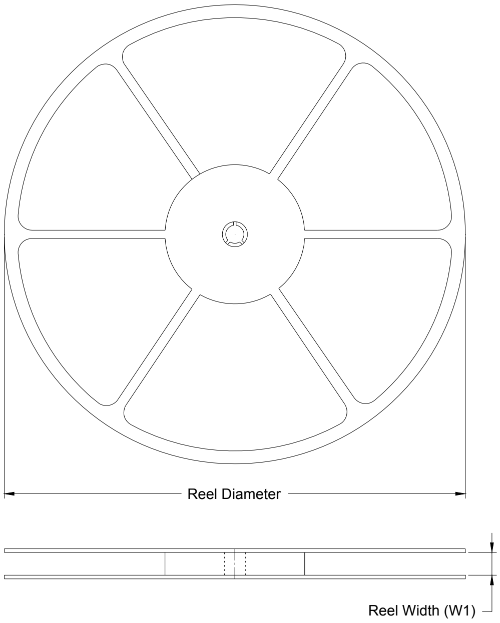


RECOMMENDED LAND PATTERN (Unit: mm)

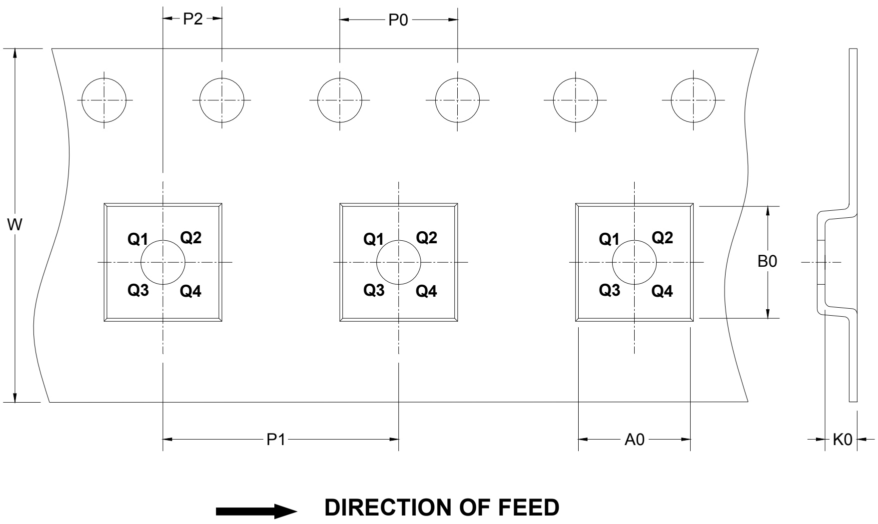
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	**MAX**	**MIN**	**MAX**
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	2.900	3.100	0.114	0.122
D1	2.300	2.600	0.091	0.103
E	2.900	3.100	0.114	0.122
E1	1.500	1.800	0.059	0.071
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.300	0.500	0.012	0.020

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS

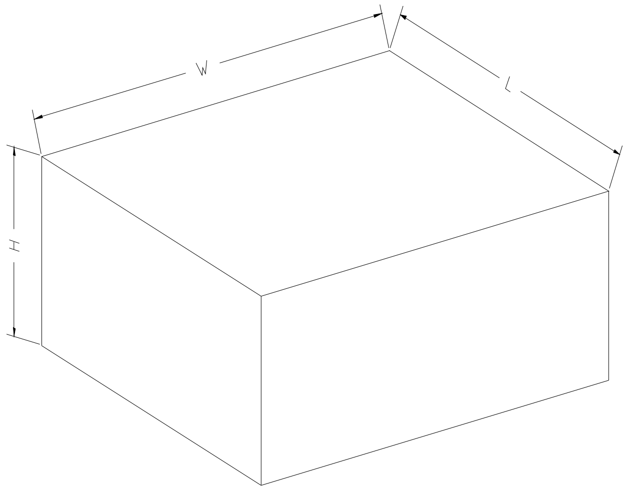


NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
TDFN-3×3-10L	13″	12.4	3.35	3.35	1.13	4.00	8.00	2.00	12.00	Q1

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13″	386	280	370	5